Transactions of the Association of European Schools of Planning • 5 (2021)
doi: 10.24306/TrAESOP.2021.01.006

THE CIRCULAR ECONOMY IN URBAN PROJECTS:

A CASE STUDY ANALYSIS OF CURRENT PRACTICES AND TOOLS

Federica Appendino[a], Charlotte Roux[b], Myriam Saadé[c], Bruno Peuportier[d]

(Received 18 October 2019; revised version received 10 July 2020; final version accepted 10 September 2020)

Abstract

Over the last decade, the concept of the circular economy (CE) has gained momentum among practitioners, politicians, and scholars because of its promise of achieving sustainability goals. However, there is still a need to demonstrate and assess the positive environmental impacts of the CE. With respect to the building sector, the CE is still a relatively new topic. To date, research has tended to focus primarily on the macro-scale (cities or eco-parks) and the micro-scale (manufactured products or construction materials). Nevertheless, the often-neglected built environment is also expected to play a crucial role in the transition towards a CE due to its high contribution to various environmental burdens. This paper contributes to this growing area of research by reviewing four cases of 'circular neighbourhood' projects in Europe. First, a conceptual framework analysis is defined and applied to the cases. Second, CE initiatives and actions are identified and classified using interviews and document analysis. Third, the use of assessment tools within these CE projects is investigated. The results demonstrate a diverse representation of the CE paradigm and the growing role played by the assessment tools.

Keywords

Circular economy, life cycle assessment, urban project, circular neighbourhood

a (Corresponding author) ESPI Paris – ESPI2R and Lab'Urba Laboratories. E-Mail: f.appendino@groupe-espi.fr

b Ecole des Ingénieurs de la Ville de Paris - Lab'Urba Laboratory. E-Mail: charlotte.roux@eivp-paris.fr

c Université Gustave Eiffel – EMGCU Laboratory. E-Mail: myriam.saade@univ-eiffel.fr

d MINES ParisTech, PSL Research University, CES - Centre for Energy efficiency of Systems.
E-Mail: bruno.peuportier@mines-paristech.fr

1. Introduction

Over the last 10 years, the concept of the circular economy (CE) has gained momentum in politics, business, and academia (Kampelmann, 2016; Reike, et al., 2017) as a means by which to overcome the contradictions that exist between economic and environmental prosperity (Geissdoerfer et al., 2017). The current economic model, characterised as 'linear' and based on a 'take-make-consume-throw away' approach of resources, is reaching its limits. In contrast, the CE forms an "economic system of trade and production which, at all stages of the product lifecycle, aims to increase the efficiency of resource use and reduce the impact on the environment, while developing the well-being of individuals" (ADEME, 2014, p.4). For these reasons, the CE already represents a core theme of major European plans and regulations (Petit-Boix and Leipold, 2018), such as the 'Circular Economy Package' adopted in 2015.

Today, several disciplines ranging from economics to urban planning are studying CE and how it can interact with, and contribute to, sustainable development issues (Kirchherr et al., 2017). However no univocal or shared definition of CE has yet been developed, despite wide dissemination of the concept (Prieto-Sandoval et al., 2017). CE constitutes an evolving notion (Merli et al., 2018), which is rather ambiguous and vague (Korhonen et al., 2017), and whose potential 'still needs to be unlocked' (OECD, 2020).

The built environment, given its important contributions to several environmental issues, is supposedly one of the main targets of CE strategies (Norouzi et al. 2021). However, scientific literature on the subject remains limited (Adams et al., 2017; Bocken et al., 2017), and concrete applications of the principle have so far only been slowly implemented (Adams et al., 2017; Pomponi and Moncaster, 2017; Densley Tingley et al., 2018). The CE is mainly understood as waste recycling and management (Ghisellini et al., 2018), and the potential effects of its implementation at an urban scale have been poorly investigated (Haupt et al., 2017). In addition, little consensus exists with regards to how best to approach and deal with this concept in the building sector, whilst the knowledge and tools required to enact it have yet to be developed (Leising et al., 2018).

The international scientific community has called for a better understanding of the roles played by the built environment in translating the CE concept into action. There is also a need to demonstrate and assess the environmental impacts of such translation. Implementing CE initiatives not only generates potential benefits, but also a number of environmental risks. 'Closing the loop' does not always positively affect the environment, and therefore 'circularity' should be assessed with relevant indicators (Kampelmann, 2016; Petit-Boix and Leipold, 2018). The CE is supposed to be not an end *per se*, but a means to an end as it provides tangible opportunities to do 'more with less' (OECD, 2020) and it is necessary to ensure implementation of the most environmentally relevant initiatives. For this reason, the application of systemic methods and tools corroborating the environmental relevance of the CE applied to the built environment is now required (Haupt and Zschokke, 2017; Haupt et al., 2017).

This paper explores how CE is (or plans to be) implemented at the neighbourhood scale, and which assessment tools are used. In the following sections, this paper provides an analysis of four 'circular neighbourhood' projects located in Europe. The next section briefly summarises the debate within existent literature pertaining to the CE in the built environment. Thereafter, the third section describes the methodology used in this study, whilst the fourth section presents the analysis of the case studies. The fifth section compares and discusses the main findings of this paper. Highlighting a diverse representation of the CE paradigm in urban projects corresponding to a wide range of practices, our analysis stresses the importance of assessing circular practices. Thereby it points to the need for adequate tools to avoid the implementation of actions promoted as circular, but potentially leading to environmental burdens.

2. The CE in the Built Environment: Fom the 'Circular City' to the 'Circular Neighbourhood'

The CE approach has gained momentum in the field of urban sustainability. Several studies, as well as some international meetings, have investigated the roles that the CE can play in ensuring the more sustainable development of cities. References on the subject are growing (Cities Foundation, 2017; Ellen MacArthur Foundation, 2017; Prendeville et al., 2018). From existent scientific literature, Pomponi and Moncaster (2017) identify three scales of CE deployment: the 'macro scale' of cities, the 'meso scale' of buildings, and the 'micro scale' of construction elements. Academic research has so far consistently focused on the macro scale, through the assessment of urban metabolism and eco-parks, as well as on the micro scale; particularly materials and building components. The meso scale remains, however, poorly investigated.

Considering their pressures on the environment, urban research on the CE has focused on 'circular cities'. Several cities, such as Berlin, Rotterdam, Paris, London, Milan, and Amsterdam have recently adopted strategic plans and are launching specific actions and projects to make their economies more circular. For instance, in 2014 the City of Amsterdam adopted The Circular Metropolis Amsterdam 2014–2018, a strategic document which aimed to transform the city into a competitive and sustainable European metropolis. This document, which comprises part of the Amsterdam Smart City initiative, relies on the City Circle Scan approach and identifies areas where major CE progress can be made. Based on this tool, Amsterdam decided to focus on the construction sector as well as the organic production and biomass sectors. In addition, Amsterdam became a Fab-City in 2016; part of an international initiative which brought approximately 20 cities together with the goal of their becoming self-sufficient. Similarly, the City of Rotterdam also launched its 'Smart City Initiative', characterised by a great focus on the transition to a CE. The main objectives on the topic are outlined in the Roadmap Circular Economy Rotterdam adopted in 2016. The actions proposed sought to ensure the city's sustainable and circular development by 2030 and are based on the results of the Rotterdam Metabolism study which provided a comprehensive picture of urban flows. Rotterdam's CE strategy focuses primarily on the city's port area and the implantation of biosourced projects (Prendeville et al., 2018). In 2017, London and Paris also developed guidance documents. Following the 2015 General Assembly of the Circular Economy, Paris adopted its first Circular Economy Plan 2017–2020 and its operational roadmap. London similarly published a Circular Economy Route Map, which contains actions involving the construction, food, textile, plastic, and electrical industries. A complementary economic analysis estimated at £2.8bn the benefits of the CE in terms of wealth creation and employment. Initiatives and actions, such as those outlined above, are multiplying in parallel with the creation of global networks; bringing cities together. The Circular Europe Network (CEN), for example, has gathered dozens of European cities together to exchange best practice. At the international level, the Open Source Circular Economy (OSCE) organisation collects innovative solutions linking the CE and open data.

As noted above, existent research on the CE has dedicated little attention to the meso scale, even though a number of authors have stressed the importance of orienting CE research towards the built environment and the building scale (Glass et al., 2017; Pomponi and Moncaster, 2017; Leising et al., 2018). In Europe, the built environment accounts for almost half of total energy consumption, and more than 50% of all extracted materials (BPIE, 2011). In France, it is responsible for nearly 40% of energy consumption, 60% of electricity consumption, and approximately a quarter of national greenhouse gases emissions (ADEME, 2012). In addition, the construction sector generates nearly three-quarters of national waste (by volume) (CGDD, 2019), and consumes approximately 20 to 30,000 Ha of natural areas per annum (France Stratégie, 2019).

In this context, the built environment could become an essential cornerstone for the implementation of effective CE strategies in cities. Several authors have pointed out that the 'neighbourhood scale', linking cities and their building, is the most relevant scale at which to address different environmental problems (Lotteau, 2017). In Europe, attention paid to the neighbourhood scale has become central to sustainable city discourses (Souami, 2009). However, research on the application of the CE in neighbourhoods remains limited and there has been a lack of comprehensive studies that have reviewed recent advances. A number of pathfinder projects are, however, emerging and the number of 'circular urban projects' is increasing in practice; raising questions about their effects on urban project dynamics, as well as their environmental performances. To answer these questions, assessment tools have been developed (Popovici et al., 2004; Herfray et al., 2010; Roux et al., 2013), and applied to the design of urban projects at the neighbourhood scale (Peuportier 2005, 2015; Peuportier et al., 2012). However, only limited attention has been paid to the characterisation (Appendino et al., 2018) and the evaluation of the environmental impacts of such projects (Girard and Nocca, 2019). A recent literature review pointed out that current academic discourses focus only marginally on CE indicators and assessment tools (Appendino et al., 2018). To date, assessment frameworks have not provided adequate tools to effectively measure progress made in the field (OECD, 2019). Given this, the present paper addresses two questions:

- Q1) How can the CE be implemented in neighbourhoods?
- Q2) What assessment tools are used?

3. Methodology

This study analyses and compares four case studies of 'circular neighbourhoods'. The case study method was selected because it enables theory and practice to be integrated, and was aptly suited to the exploratory nature of this research (Leising et al., 2018). First, we conducted a literature review to identify relevant 'circular neighbourhood' cases. In addition to scientific papers, reports and urban planning documents were found within this corpus of reviewed work. Scientific literature was mostly limited to theoretical discussions with little attention given to the neighbourhood scale. The research involved texts in English, French, and Italian. Four case studies were found and selected: the first concerns the neighbourhood of Buiksloterham (Amsterdam), which will be developed into a sustainable district, based on circular principles; the second neighbourhood is Kera (Espoo), an industrial area destined to become a 'liveable CE neighbourhood'. The last two cases are located in Paris; the Groues, and Saint-Vincent-de-Paul eco neighbourhoods, both considered to be 'CE living labs'. The selection of all the cases was guided by two fundamental criteria: the willingness to implement CE principles at the neighbourhood scale, and the existence of a comprehensive CE strategy at the city level within which the individual projects fit. Following case selection, CE initiatives and actions were identified and classified using document analysis, whilst data collected through semi-structured interviews with local stakeholders involved in the projects was integrated into the study's considerations. Finally, we defined a conceptual framework analysis based on three criteria: CE practices, strategic city scale integration, and tools employed. We applied this analytical framework to the four case studies in order to aid comparative analysis and comment.

4. Case Studies Analysis

The selection of the four case studies relied on their innovative characters and the central relevance of the CE to each case. In all four urban projects, the CE was a key pillar.

Table 1 - Case Studies

Case	Buiksloterham	Kera	Les Groues	Saint-Vincent-de-Paul
City and Country	Amsterdam, Netherlands	Espoo, Finland	Nanterre, France	Paris, France
Size	1000 hectares	22 hectares	65 hectares	4 hectares
Site	Redevelopment of industrial areas	Redevelopment of industrial areas	Redevelopment of industrial areas	Redevelopment of hospital complex
Main Objective	'key innovation zone for circular development'	'a showcase district for circular economy'	'circular economy living-lab'	'a privileged space to develop and test circular economy
Starting date	Around 2015	Around 2018	Around 2018	Around 2018

Source: Authors

As illustrated in Table 1, despite differences in size and location, the analysed neighbourhoods presented some common features. For instance, all four cases constitute urban regeneration projects, and each is experimental, and functions as a showcase to test CE principles. It is also important to underline that all the projects are recent and at different stages of implementation. None of them is yet completed. For this reason, the analysis here focuses on the design phases of each project.

4.1. Buiksloterham, Amsterdam

Amsterdam represents one of Europe's pioneering cities in terms of its approach to the concept of the CE. The CE constitutes one of the main pillars of the Sustainable Amsterdam Agenda (2015). The Agenda sets targets for reducing energy consumption by 20% and increasing renewable production by 20% compared to 2013 (Hoek et al., 2017). In this strategic document, the Buiksloterham neighbourhood is considered 'an engine for the broader transition of Amsterdam' (Metabolic, 2015, p.12) towards a circular city.

Part of a larger redevelopment plan for the northern banks of the river, Buiksloterham is characterised by abandoned factories, wasteland, and docks. Once the site of Amsterdam's most polluting industries, the neighbourhood could become, according to the city's vision 'a key innovation zone for circular urban development' (Metabolic, 2015, p.25). The municipality proposed a bottom-up approach for the area's redevelopment in order to build a more comprehensive sustainability strategy. To this end, approximately 20 stakeholders, including local actors, organisations, associations and companies, signed the Circular Buiksloterham Manifesto in 2015. This innovative manifesto included shared guiding principles for redeveloping Buiksloterham; a zero-waste objective, the implementation of clean technologies, and the use of biosourced materials.

Recognising the urgency of having a clear operational strategy, all involved stakeholders commissioned an Urban Metabolism Scan in order to understand the neighbourhood's complete workings from a systemic perspective. The analysis, carried out by the consultancy Metabolic and published in 2015, involved three stages: context analysis, stakeholder analysis, and metabolism analysis. The Urban Metabolism Scan focused on material and energy flows, biodiversity, environmental conditions, socio-economic factors, local actors, urban planning documents and plans, health, and the area's living environment. A study of the neighbourhood's CE potential followed this analysis. From this, the priority objectives for redeveloping Buiksloterham as a 'living lab for CE' by 2034 were translated into eight priority issues (Table 2).

Table 2 - Buiksloterham's Objectives

OBJECTIVES	
Energy	Buiksloterham is energy self-sufficient with a fully renewable energy supply
Materials & products	Buiksloterham is a zero-waste neighbourhood that with a near 100% circular material flow
Water	Buiksloterham is "rainproof " (rainwater and wastewater recovery) and has near 100% resource recovery from wastewater
Ecosystems and biodiversity	Buiksloterham's ecosystems are regenerated and its natural capital base is self-renewing
Infrastructure & mobility	Buiksloterham's Infrastructure is maximally-used and local mobility has zero emissions
Socio-cultural	Buiksloterham has a diverse and inclusive culture, and a high quality, liveable environment
Economy	Buiksloterham has a strong local economy that stimulates entrepreneurship and encourages the creation and exchange of multiple kinds of value (social, environmental, cultural)
Health & wellbeing	Buiksloterham is a healthy, safe and attractive environment with recreational activity space for all residents.

Source: Metabolic (2015)

With regard to the built environment, it is interesting to note that a Circular Building Standard applies to all renovations and new constructions. This innovative assessment tool, which is still in a development phase, would allow tax credits to local developers once the standard has been reached. Among the key recommendations, all buildings' roofs are equipped for clean energy production and rainwater collection, and all materials are registered in a digital passport to facilitate their identification. In addition, prefabricated building elements are preferred, facilitating deconstruction and reuse. To ensure these objectives, an action plan was first developed. The proposed actions consisted of two types: systemic actions aimed at ensuring the district's long-term transition, and technical actions which addressed specific issues. To define these actions, prioritisation work was carried out. Those actions which were considered most urgent related to new constructions and infrastructure, whilst priority actions centred upon the energy efficiency of the existent building stock, the flexibility of new infrastructure, the development of fresh mobility, and water recovery and management.

The project is currently underway, but Buiksloterham is also developing through local initiatives. Two pioneer projects have come to the fore: De Ceuvel – which consists of retrofitted houseboats, and Schoonschip; a new built floating housing community. Both sites have ambitious sustainability and circularity targets: 100% renewable electricity, heating, and hot water; 100% water self-sufficiency; 100% wastewater management; 50-70% nutrient recovery; and 10-30% food production on site (Metabolic, 2016).

4.2. Kera, Espoo

The City of Espoo, Finland, is a pioneering city in terms of sustainable development; as demonstrated in the comparative assessment study of 15 European cities carried out in 2017 by the University of Tilburg (Zoeteman et al., 2017). Initiatives led by the municipality within the framework of the Helsinki Metropolitan Plan, as well as the Helsinki Metropolitan Area Smart and Clean Cooperation project, are multiplying, and the city aims to become carbon neutral by 2050. In most cases, the CE constitutes a central issue in these strategic documents

In this context, the Kera neighbourhood, located in the eastern part of Espoo and close to the railway station, presents itself as a unique opportunity for the municipality to experiment with innovative CE solutions. Previously an industrial area, and the site of the headquarters of Finland's largest distribution group, Kera will be transformed into a mixed-use and dense neighbourhood of 14,000 residents. In addition to commercial services and offices, the project includes day-care centres, schools, sports, and recreation services. The municipality's objective is to transform this industrial park into a liveable neighbourhood with a strong CE focus by 2035 (Table 3). The goal of the project is to make Kera an international showcase district for the CE. With this perspective, the case of Kera was presented as an example of a 'circular neighbourhood' at the 'World Circular Economy Forum' of 2017.

Table 3 - Kera's Objectives

OBJECTIVES				
The first Nordic neighbourhood built according to the CE principles	A 20-minute walkable neighbourhood, where everyday destinations are within walking distance	A sustainable planning and construction process, by using ecological and innovative building technologies and materials	A network of green infrastructure and multifunctional public places	A versatile, dense, mixed use, human scale urban fabric

Source: BM-Architects et al. (2016)

The ongoing project was the winner of the Kera Challenge which was launched in 2015 with the aim of identifying a vision and project for Kera's future, based on the principles of sustainable urban planning and CE. In the winning project, Co-op City, a CE is supposed to be achieved through a 'large range of different measures, from boosting resources efficiency and creating closed loop systems to involving the local residents' (BM-Architects et al., 2016, p.5). The main solutions to support the development of a CE put forward in the project are related to the recycling of existent industrial architecture, the development of a sharing economy and digital services, the creation of mobile platforms for smart mobility services, and the realisation of a resilient green infrastructure within public spaces.

With regard to the built environment, the Kera Design Manual describes the principal CE practices. In the manual, all constructions are required to be biodegradable or fully recyclable so as to aid with the gradual phasing out of construction waste. The flexibility of the constructed buildings represents one of the document's principles. This flexibility provides the basis for the possibility of a future 'circular regeneration' of building stock. In this perspective, Life Cycle Assessment (LCA) will be mandatory. Concerning reuse and recycling, attention is given in the project to both existing materials, such as asphalt, which must be recovered, and to the construction elements of existing halls, such as beams, slabs, and columns. In addition, the temporary use of some existing buildings is highlighted as a CE practice. For example, during building construction, the ground floor of the halls will be used for the temporary storage of materials and elements to be reused or recycled. Furthermore, the halls' structure will be reused when constructing new buildings or outdoor spaces. In addition, it is interesting to note that 100% of the primary energy demands of the future neighbourhood will be produced from renewable sources; some produced on site. Solar, geothermal, and wind energy production is planned, and these will feed into an intelligent energy grid. For new constructions, passive solutions are preferred.

4.3. Les Groues, Nanterre

The urban redevelopment project of the Groues in Nanterre, led by the *Etablissement Public d'Aménagement de la Défense Seine-Arche* (EPADESA), aims to create a mixed district, offering housing, office space, shops, services and equipment, accommodating nearly 12,000 inhabitants. Close to the business district of La Défense and served by a future line of the Grand Paris metro, the Groues neighbourhood covers approximately 65 hectares. It is characterised by numerous wastelands and dilapidated buildings. The project and its realisation are recent. In 2015, the EPADESA approved a Strategic Operational Project and in December 2016, the first *zones* *d'aménagement concerté* (ZAC – integrated development zones) were created. The first development contracts are currently being awarded, and the process of construction is expected to continue until 2030 (ADEME, 2017).

The goal of the Groues development project is to become a 'laboratory for a dynamic, green and inclusive neighbourhood' (EPADESA, 2016, p.22) and, more generally, to become an experimental laboratory for the sustainable city of tomorrow. In particular, the project aims to be exemplary in environmental matters and to obtain *Label EcoQuartier* status, by becoming a positive energy territory. Five strategic axes constitute the foundation of the project:

Table 4 - Les Groues' Objectives

OBJECTIVES				
Energy transition and the fight against climate change	Biodiversity and respect for natural resources	Protection against nuisances and creation of healthy and comfortable environments	Creation of an economic innovation ecosystem integrating a diversity of actors and co-design approaches	Laboratory of a circular and solidarity economy

Source: EPADESA (2016)

The CE represents one of the main pillars of the project's sustainable development strategy. Winner of the Call for Expression of Interest Circular Economy and Urban Planning launched by the *Agence de la transition écologique* (ADEME - Agency for Ecological Transition) in 2015, the Groues project offers a location in which to apply the CE in an experimental manner at both neighbourhood and territorial scales. As ADEME (2017) notes, the actions planned for the CE are multiple and the built environment receives particular attention through the local management of construction site waste (choice of materials, grey energy, and local management of backfill/burial).

Furthermore, the ZAC project plans to place the built environment at the centre of the CE approach, as well as the project's overall energy efficiency ambitions. To this end, 'life cycle thinking' is encouraged with it being stated that 'The building must be understood in all its spatial and temporal integrity by real estate operators, who must understand the life cycle of their building: its manufacturing processes and materials, its duration over time and its capacity to adapt and evolve up to its deconstruction' (EPADESA, 2016, p.77). The concepts of 'grey energy' and 'transformation capacity' are also central. Other CE practices are highlighted as well, such as rainwater harvesting, building flexibility and modularity, neighbourhood waste harvesting, and the reuse of existing buildings.

In addition, EPADESA launched two calls for projects in 2016; aimed at inspiring innovative reflections and experiments on the CE theme. The first one concerns temporary urban planning approaches which enable an expansion of the lifespans of existing buildings. The ephemeral initiatives presented were highly diverse and ranged from soil remediation to the reuse of building materials, or even innovative start-up incubators. The second one directly concerns new constructions and seeks to develop innovative CE solutions in the construction sector. LCA has been applied to the design of 5 office buildings, and the environmental benefits of recycling have also been studied. The project is underway and after this first phase of experimentation, the challenge is to bring overall coherence to these CE actions at the neighbourhood level. In addition, there is a willingness to establish fruitful local alliances around the reuse of materials.

4.4. Saint-Vincent-de-Paul, Paris

Located in the 14th arrondissement of Paris, the former Saint-Vincent-de-Paul hospital remained vacant for approximately 10 years after having been decommissioned. In 2014, it was acquired by the Municipality of Paris with the latter intending to transform it into an innovative eco-neighbourhood (City of Paris, 2017). Covering an area of 3.4 hectares, the redevelopment project of the Saint-Vincent-de-Paul Hospital presented a rare opportunity for urban transformation in the heart of Paris' particularly dense urban fabric. In particular, the objectives pursued by Paris for the site are as follows:

Table 5 - Saint-Vincent-de-Paul's Objectives

OBJECTIVES			
Create a predominantly residential area, promoting social diversity	Lead an exemplary environmental approach, making Saint-Vincent-de-Paul an innovative and emblematic eco-neighbourhood for the city	Think of public and open spaces as green spaces, whether on roofs, floors or facades	Enhance the heritage and history of the site

Source: P&MA (2020)

In December 2016, the ZAC was created and *Paris & Métropole Aménagement* (P&MA), the developer appointed by the City of Paris, embarked on transforming the area. The construction work began in 2018, and it was envisaged that there would be approximately 60,000 m^2 of total floor area, broken down into housing (including 50% social housing), facilities, equipment (including a school and a gymnasium), shops, and a public garden (P&MA, 2020). With regard to the built environment, the future district aims to become an exemplary showcase for the entire city thanks to its ambitious environmental approach. Specifically, the Resilience Strategy adopted in 2017 described the project as the city's first resilient and carbon-neutral neighbourhood. In compliance with the city's framework documents, and as a 'pilot district for sustainable development' (City of Paris, 2017, p.86), the project aims to reduce impacts on the environment and to promote innovative technologies. It provides for reversible buildings, pooling resources, conserving and converting 60% of existing buildings, developing renewable energies, certifying new constructions, optimising energy systems, and recovering waste.

In addition, ZAC Saint-Vincent-de-Paul aims to be a privileged space to develop the principle[s] of the CE (P&MA, 2020). Several actions have been put forward in the field of the CE with regard to the orientation of the Parisian CE plan. For instance, attention is being paid not only to the reuse of certain buildings, to limit demolitions, and to the development of smart grids, to speed up ecological transition, but also to the social and inclusive economy. The project also has specific objectives related to the waste generated during the construction and demolition phase, including material and architectural elements recovery and energy recovery from waste.

Reflecting the aims outlined above, the recovery of dismountable elements, that might be reused, is planned for all the buildings. This process is supported by an inventory distributed to all the potentially interested local organisations. A specific project management assistance service for sustainable development is planned to ensure the delivery of these objectives. For both new construction and rehabilitation, architects have to demonstrate the proportion of reused materials that will be incorporated into their plans at the design phase of their project. CE indicators are being developed and will be introduced into the project's Building Information Modelling (BIM) to produce overall indicators at the neighbourhood level. As part of the PULSE-PARIS research project, funded by ADEME[1], LCA will also be used to evaluate St Vincent de Paul's CE actions related to deconstruction, renovation, and new constructions.

5. Cross-Case Comparisons and Discussion

The results of the analysis are summarised in Table 6 and compared by applying an analytical grid which was based on the following criteria: CE practices, strategic city scale integration, and tools employed. Following this three-step analysis, some significant similarities are noted.

1 The PULSE-PARIS research project aims to improve the relevance and operationality of eco-design approaches for urban projects in line with the CE strategic plans of the City of Paris. In particular, the project focuses on life cycle assessment (LCA) tools at the neighborhood scale, which are still in their infancy. The project will synthesis strategic approaches at the city scale and eco-design approaches on the urban project level, in order to verify the coherence and articulation between these decision-making levels. The evaluation of CE practices on this scale using LCA is innovative and would make it possible to better understand the environmental benefits of these practices. (The research project is led by the École des ingénieurs de la ville de Paris (Engineering School of the City of Paris – EIVP) and MinesParisTech).

Table 6. Cross-Case Comparison

		Buiksloterham	Kera	Les Groues	Saint-Vincent-de-Paul
Strategic city scale integration		Sustainable Agenda Smart City Initiative Circular Amsterdam	Sustainable Agenda Smart City Initiative	EcoQuartier Label	Resilience Plan Territorial Climate Plan Circular Economy Plan
Tools employed		Circular Building Standard Materials digital Passport MFA	Kera design manual LCA Buildings	(LCA Perspective)	LCA Building Carbon Footprint Municipality's assessment tool
CE practices	Energy	100% renewable energy PassivHaus Label Local energy production 100 % energy recovery from wastewater	100% renewable energy PassivHaus Label Local energy production (Géothermal, Eolic) Smart Grid	70% renewable energy Energy recovery from wastewater	40% electricity by photovoltaic panels PassivHaus Label Smart Grid
	Waste and materials	Reuse materials 100% "circular material flow" Deconstruction Zero waste objective	Reuse materials and construction elements Biodegradable or recyclable materials	Reuse of materials and existing buildings Local management of construction and demolition waste Waste recovery and valorisation	Reuse of materials and existing buildings Local management of construction and demolition waste Waste recovery and valorisation
	Water	Rainwater collection	"Green and Blue Tools"	Rainwater collection	Rainwater collection
	Other	Temporary occupancy of buildings Buildings' flexibility Prefabricated constructions and structures Auto-construction Urban agriculture and local food production	Temporary occupancy of buildings Buildings' flexibility	Temporary occupancy of buildings Buildings' flexibility Urban agriculture	Temporary occupancy of buildings Urban agriculture Short circuits CE stakeholders point of reference

Source: Authors

With regards to similarities, it is firstly noted that all four projects have been integrated into strategic documents which address sustainable development and the CE of each city, such as smart city initiatives or resilience and climate strategies. These documents always present the projects as 'experimental demonstrators' of the CE in urban projects. Therefore, there is always a strong link between the strategic planning scale and the operational scale of the individual urban projects. However, it is important to note that, in all the reviewed cases, the CE is often seen as one of the pillars of sustainable development, and that sometimes no distinction has been made between the proposed actions that are related to the CE, and those that are more focused on issues of sustainable development.

Second, similarities are also evident with respect to the CE practices identified in the four projects. With regard to the case studies analysis, it is possible to classify four categories of recurrent practices: energy, water, waste, and other. All of the cases demonstrate an insistence on flexibility and the temporary occupancy of buildings; the reuse of building materials, elements and existing buildings; and eco-construction. An important focus that is common to all of the projects is the emphasis placed on the energy aspects of new buildings, with details given in each case of the precise standards that are to be achieved.

All of the case studies also favour reuse over recycling. The focus is primarily on the reuse of existing structures; the most preferred option in each of the projects. For this reason, the flexibility of new buildings is also emphasised, to ensure an easy dismantling and further reuse of structures in the future according to renewed demands. Secondly, all elements such as doors, windows, and interior furnishings should be recovered and reused whenever possible. All of the case studies refer to selective deconstruction and disassembly as being best practice. It is also notable that there is a need for the temporary storage of materials and elements, and that where possible this should be close to the given site's location. This is particularly difficult in dense urban areas such as Paris, where space is at a premium; it is much more feasible in the cases of Kera and Buiksloterham, where substantial parts of the project areas have been vacant for a number of years. It is also the case that the marketplace for second-hand building elements and materials is still immature, despite the development of digital platforms connecting different actors, supply, and demand. Very precise rules (technical, legal and economic) also govern the use of construction materials; limiting the possibilities of reuse (ADEME, 2016). Moreover, all four cases advocate temporary use of the buildings since these interventions seem to require relatively low investment and are easily reversible. Other CE practices highlighted by at least two cases relate to waste management, particularly construction site waste, as well as water management and urban agriculture.

More generally, the comparative table indicates a wide variety of CE practices, especially with regards to environmental issues. The other two pillars of sustainable development, economic and social, do not appear to be central. Despite the great number of CE practices within these cases, their implications in environmental, economic and social terms do not appear to have been studied in depth. Some practices remain vague. Quantified and measurable targets relate almost exclusively to energy issues.

Moreover, there is no consensus regarding the tools employed. For instance, the Dutch and Finnish cases rely on *ad hoc* assessment methodologies. These tools, mostly intended for design and construction phases, would set precise standards to be achieved in the field of circular construction. However, they are still under development and very little information about them is presently available; though the digital passport proposed in the Buiksloterham case appears to be very innovative with regard to the easy identification and valuation of materials available at the end of buildings' useful lives. Furthermore, only the case of Buiksloterham has mobilized metabolism analysis. Based on the material flow analysis (MFA) methodology, this analysis looks not only at the type and quantity of physical flows (energy, water, materials), but also at local socioeconomic flows. This well-identified assessment tool is often coupled with the CE, but according to Elia et al. (2017), it is not sufficient to validate the relevance of CE practices, because it does not explicitly account for environmental impacts. MFA is an important territorial knowledge tool, but it does not prioritise and make decisions between different CE actions.

Other tools, such as LCA, could support such decisions. LCA appeared in the early 1990s, and even if the expression CE was not employed at that time, most ideas corresponding to the CE were already integrated into it. For instance, recycling is one issue that has been particularly studied to reduce environmental impacts, see for instance (Schrijvers et al., 2016). In this regard, it is interesting to note that the 'life cycle perspective' is central in all cases, but not necessarily associated with LCA tools. Some scholars consider LCA to be the most comprehensive method for the assessment of environmental impacts and CE requirements (Elia et al., 2017). Nevertheless, in the Kera cases, LCA is planned to be used only at the building scale and for new constructions. The assessment of CE practices is not directly mentioned, except in Saint Vincent de Paul. The scale of the neighbourhood is never mentioned for the evaluation of CE practices using LCA. This can lead to contradictions because, as demonstrated during the 63rd discussion forum on LCA (Haupt and Zschokke, 2017), 'circularity' does not always positively affect the environment and contradictions can arise. Purely by way of example, it can be noted that while material recovery practices can reduce the consumption of natural resources, they are not necessarily relevant from climate or ecosystem points of view. In the case of a recycling site far from a worksite, the transport of heavy materials may reduce or even cancel out the environmental benefits of recycling. Similarly, the flexibility and modularity of spaces must be studied in conjunction with summer comfort: the systematic use of lightweight and low inertia partitions can lead to overconsumption of air conditioning compared to a design that has heavy partitions. Moreover, while it is true that the rehabilitation of a building generates less waste, it can also generate other environmental impacts.

Despite overlaps, MFA and LCA have different purposes: MFA aims to reduce the different flows, by identifying and quantifying them, whilst the LCA aims to characterize these different flows in order to quantify and reduce their possible impacts on the environment. Both tools could, therefore, be complementary for CE assessment, but they are not coupled in the case studies. Finally, it is important to note that all these projects are currently underway, and this contributes to a lack of precision regarding the performance that will actually be achieved upon their delivery. For this reason, the focus of this article is mainly on the design and construction phase which, in turn, raises questions as to how the CE can be perpetuated in urban projects in subsequent phases of development.

6. Conclusion

The literature review shows that the CE provides a useful perspective for rethinking sustainable urban development. The CE is becoming part of the urban agenda. Nevertheless, the CE remains a new topic for urban planning and research is lacking with respect to the application of CE principles to the built environment. This raises the questions of how the CE is concretely implemented in urban projects, and how to measure their environmental benefits. To address this gap, this paper provides a comparative analysis of four 'circular neighbourhoods' to identify and discuss the CE practices implemented, and the assessment tools utilised. The results of this analysis indicate a large panel of CE practices, focusing primarily on environmental dimensions, and an important issue of experimentation and consolidation of the CE models applied to urban projects. The case studies also underscore the additional requirements needed for the implementation of the CE, such as the need to store materials to be reused.

More generally, examining the different CE practices identified in the case studies shows significant similarities between eco-neighbourhood projects. Within sustainable eco-neighbourhoods literature, local and renewable energy production, rainwater collection, and urban agriculture are practices typically put forward. The main difference in these cases is a new emphasis on aspects related to deconstruction, management of construction and demolition waste, as well as building and materials reuse. Furthermore, both the referenced literature and the case studies reveal a limited use of indicators and assessment tools to establish the relevance and prioritisation of these practices. This raises questions regarding how to ensure that the CE generates real environmental benefits, and how to measure them. These assessment tools, when used, are useful in helping to avoid risks of greenwashing, and guarantee the adoption of more sustainable and environmentally friendly practices.

Further steps in this research field are needed and require the study of other cases and tools. In addition, several authors have highlighted the ability of LCA to evaluate aspects of the CE (Elia et al., 2017; Fregonara et al., 2017; Giorgi et al., 2017; Haupt and Zschokke, 2017; Ghisellini et al., 2018; Zanni et al., 2018; Peña et al., 2021). They underline two key characteristics of LCA: the 'life-cycle thinking' perspective, which should also be the basis of the CE, and environmental impact assessment. The relevance of LCA is becoming increasingly apparent to experts, who are emphasising the importance of LCA in the implementation of CE strategies. In this context, one of the objectives of the PULSE-PARIS project involves the concrete application of the LCA method to evaluate identified CE practices at the neighbourhood scale in order to study its relevance and propose possible improvements.

7. Acknowledgement

This article presents some of the first results of the PULSE-PARIS research project, currently under progress and funded by the French environmental and energy management agency (ADEME).

References

Adams, Katherine Tebbatt, Mohamed Osmani, Tony Thorpe and Jane Thornback (2017) Circular Economy in Construction: Current Awareness, Challenges and Enablers. *Proceedings of the Institution of Civil Engineers: Waste and Resource Management*, 170 (1). https://doi.org/10.1680/jwarm.16.00011

ADEME (2012) *Énergie et climat: Chiffres-clés.*

ADEME (2014) *Économie Circulaire: Notions.*

ADEME (2016) *Identification des freins et des leviers au réemploi de produits et matériaux de construction.*

ADEME (2017) *Economie Circulaire - Un Atout Pour Relever Le Défi de l'aménagement Durable Des Territoires'.* Available at: http://www.ademe.fr/sites/default/files/assets/documents/livre-blanc-economie-circulaire-defi-amenagement-durable-territoires-010264.pdf

Appendino, Federica, Charlotte Roux and Bruno Peuportier (2018) *PULSE-PARIS Livrable 1*. ADEME.

BM-Architects, WSP, Päivi Raivio, Setlementtiasunnot Oy and Forum Virium Helsinki (2016) *Kera Co-Op City: New Nordic Neighborhood.* Available at: https://www.nordicinnovation.org/sites/default/files/inline-images/NBCC-Kera-COOP-CITY-booklet_small.pdf

Bocken, Nancy, Elsa Olivetti, Jonathan M. Cullen, José Potting and Reid Lifset (2017) Taking the Circularity to the Next Level: A Special Issue on the Circular Economy. *Journal of Industrial Ecology*, 21 (3). https://doi.org/10.1111/jiec.12606.

BPIE-Buildings Performance Institute Europe (2011) *Europe's buildings under the microscope: A country-by-country review of the energy performance of buildings.* Brussels: Buildings Performance Institute Europe.

City of Paris (2017) *Stratégie de Résilience de Paris.* Available at: https://resilientcitiesnetwork.org/downloadable_resources/Network/Paris-Resilience-Strategy-English.pdf

Cities Foundation (2017) *The wasted city approaches to circular city making.* Haarlem: Trancity.

CGDD (2019) *Bilan 2016 de la production de déchets en France.* Available at: https://www.statistiques.developpement-durable.gouv.fr/sites/default/files/2019-12/datalab-essentiel-198-bilan-2016-production-dechets-france-decembre2019.pdf

Densley Tingley, Danielle Jannik Giesekam and Simone Cooper-Searle (2018) Applying Circular Economy Principles To Reduce Embodied Carbon. In Pomponi, Francesco, Catherine De Wolf and Alice Moncaster (eds) Embodied carbon in buildings. Measurement, management and mitigation. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-72796-7_12

Elia, Valerio, Maria Grazia Gnoni and Fabiana Tornese (2017) Measuring circular economy strategies through index methods: A critical analysis. *Journal of Cleaner Production,* 142 (January), pp.2741-51. https://doi.org/10.1016/j.jclepro.2016.10.196

Ellen MacArthur Foundation (2017) Cities in the circular economy: An Initial exploration.

EPADESA (2016) *Les Groues. Plan Guide.* Available at: https://fr.calameo.com/read/00398144105d3a711cb51

France Stratégie (2019) *Objectif «Zéro artificialisation nette»: quels leviers pour protéger les sols?.* Available at: https://www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/fs-rapport-2019-artificialisation-juillet.pdf

Fregonara, Elena, Roberto Giordano, Diego Giuseppe Ferrando and Sara Pattono (2017) Economic-environmental indicators to support investment decisions: A focus on the buildings' end-of-life stage. *Buildings*, 7 (4), 65. https://doi.org/10.3390/buildings7030065

Geissdoerfer, Martin, Paulo Savaget, Nancy M. P. Bocken and Erik Jan Hultink (2017) The circular economy – A new sustainability paradigm? *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2016.12.048

Ghisellini, Patrizia, Maddalena Ripa and Sergio Ulgiati (2018) Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector: A literature review. *Journal of Cleaner Production.* https://doi.org/10.1016/j.jclepro.2017.11.207

Giorgi, Serena, Monica Lavagna and Andrea Campioli (2017) Circular economy, waste management and life cycle thinking. *Ingegneria Dell'ambiente* 4 (3). http://dx.doi.org/10.14672/ida.v4i3.1141

Glass, Jacqui, David Greenfield and Phil Longhurst (2017) Editorial: Circular economy in the built environment. *Proceedings of the Institution of Civil Engineers - Waste and Resource Management* 170 (1). https://doi.org/10.1680/jwarm.2017.170.1.1

Haupt, Melanie, Carl Vadenbo and Stefanie Hellweg (2017) Do we have the right performance indicators for the circular economy? Insight into the Swiss waste management system. *Journal of Industrial Ecology* 21 (3), pp.615-27. https://doi.org/10.1111/jiec.12506

Haupt, Melanie and Mischa Zschokke (2017) How Can LCA support the circular economy? 63rd Discussion Forum on Life Cycle Assessment, Zurich, Switzerland, November 30, 2016. *The International Journal of Life Cycle Assessment* 22 (5), pp.832-37. https://doi.org/10.1007/s11367-017-1267-1

Herfray, Gregory and Bruno Peuportier (2010) Life cycle assessment applied to urban settlements. *Sustainable Building Conference 2010*, Madrid.

Hoek, Jan Peter van der, André Struker and J. E. M. de Danschutter (2017) Amsterdam as a sustainable European metropolis: Integration of water, energy and material flows. *Urban Water Journal* 14. https://doi.org/10.1080/1573062X.2015.1076858

Kampelmann, Stephan (2016) Mesurer l'économie circulaire à l'échelle territoriale. *Revue de l'OFCE* 1 (145). https://doi.org/10.3917/reof.145.0161

Kirchherr, Julian, Denise Reike and Marko Hekkert (2017) Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation & Recycling*, 127. http://dx.doi.org/10.1016/j.resconrec.2017.09.005

Korhonen, Jouni, Cali Nuur, Andreas Feldmann and Seyoum Eshetu Birkie (2017) Circular economy as an essentially contested concept. *Journal of Cleaner Production* 175. https://doi.org/10.1016/j.jclepro.2017.12.111

Leising, Eline, Jaco Quist and Nancy Bocken (2018) Circular economy in the building sector: Three cases and a collaboration tool. *Journal of Cleaner Production* 176, pp.976-89. https://doi.org/10.1016/j.jclepro.2017.12.010

Lotteau, Marc (2017) Integration of morphological analysis in early-stage LCA of the built environment at the neighborhood scale. Theses, Université de Bordeaux. https://tel.archives-ouvertes.fr/tel-01677273

Merli, Roberto, Michele Preziosi and Alessia Acampora (2018) How do scholars approach the circular economy? A systematic literature review. *Journal of Cleaner Production* 178. https://doi.org/10.1016/j.jclepro.2017.12.112

Metabolic (2015) Circular Buiksloterham. Transitioning Amsterdam to a Circular City. Vision and Ambition.

Metabolic (2016) Circular cities. Designing post-industrial Amsterdam, the case of Buiksloterham'.

OECD (2019) *The circular economy in cities and regions.* Available at: https://www.oecd.org/cfe/regionaldevelopment/circular-economy-cities.htm

OECD (2020) *The circular economy in Groningen, Netherlands.* https://doi.org/10.1787/e53348d4-en

Norouzi, Masoud, Marta Chàfer, Luisa Cabeza, Laureano Jiménez and Dieter Boer (2021) Circular economy in the building and construction sector: A scientific evolution analysis. *Journal of Building Engineering* 44. https://doi.org/10.1016/j.jobe.2021.102704

Peña, Claudia, Bárbara Civit, Alejandro Gallego-Schmid, Angela Druckman, Armando Caldeira-Pires, Bo Weidema, Eric Mieras, et al. (2021) Using life cycle assessment to achieve a circular economy. *The International Journal of Life Cycle Assessment* 26 (2), pp215–20. https://doi.org/10.1007/s11367-020-01856-z

Petit-Boix, Anna and Sina Leipold (2018) Circular economy in cities: Reviewing how environmental research aligns with local practices. *Journal of Cleaner Production*, 195, pp.1270-81. https://doi.org/10.1016/j.jclepro.2018.05.281

Peuportier, Bruno (2015) *Energétique des bâtiments et simulation thermique. Modèles - Mise en oeuvre - Etudes de cas.* Eyrolles, Paris.

Peuportier, Bruno (2005) Towards sustainable neighbourhoods, the eco-housing project. *IV International Conference "Climate change – energy awareness – energy efficiency"*, Visegrad.

Peuportier, Bruno, Erice Vorger and Gregory Herfray (2012) LCA application in urban design. *International Symposium Life Cycle Assessment and Construction,* Nantes.

P&MA (2020) *Saint-Vincent-de-Paul. Another kind of Paris. Press Kit.* Available at https://www.parisetmetropole-amenagement.fr/sites/default/files/2020-01/DP_SVP_Nov2019_InDesign2018_TRADfull.pdf

Pomponi, Francesco and Alice Moncaster (2017) Circular economy for the built environment : A research framework. *Journal of Cleaner Production*, 143, pp.710-18. https://doi.org/10.1016/j.jclepro.2016.12.055

Popovici, Emil and Bruno Peuportier (2004) Using life cycle assessment as decision support in the design of settlements. *PLEA Conference*, Eindhoven.

Prendeville, Sharon, Emma Cherim and Nancy Bocken (2018) Circular cities: Mapping six cities in transition. *Environmental Innovation and Societal Transitions.* https://doi.org/10.1016/j.eist.2017.03.002

Prieto-Sandoval, Vanessa, Carmen Jaca and Marta Ormazabal (2017) Towards a consensus on the circular economy. *Journal of Cleaner Production.* https://doi.org/10.1016/j.jclepro.2017.12.224

Reike, Denise, Walter Vermeulen and Sjors Witjes (2017) The circular economy: New or refurbished as CE 3.0? — Exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. *Resources, Conservation & Recycling* in press. https://doi.org/10.1016/j.resconrec.2017.08.027

Roux, Charlotte, Bruno Peuportier and Gregory Herfray (2013) Dynamic LCA applied to buildings and urban districts. *Sustainable Building 2013 Conference,* Munich.

Schrijvers, Dieuwertje L., Philippe Loubet and Guido Sonnemann (2016) Critical review of guidelines against a systematic framework with regard to consistency on allocation procedures for recycling in LCA. *The International Journal of Life Cycle Assessment* 21 (7), pp.994-1008. https://doi.org/10.1007/s11367-016-1069-x

Souami, Taoufik (2009) *Écoquartiers, Secrets de Fabrication. Analyse Critique d'exemples Européens.* Éditions les Carnets de l'info. Paris.

Zanni, Sara, Isabela Maria Simion, Mariana Gavrilescu and Alessandra Bonoli (2018) Life cycle assessment applied to circular designed construction materials. *Procedia CIRP* 69. https://doi.org/10.1016/j.procir.2017.11.040

Zoeteman, Bastian, Sanne Paenen, Rens Mulder and Corné Wentink (2017) *Benchmarking sustainability performance of Espoo with selected EU Cities: A 2017 benchmark study of 15 selected high scoring cities in Northern Europe, prepared for the City of Espoo,* Finland. Telos. Available at: https://pure.uvt.nl/ws/portalfiles/portal/19971591/Benchmarking_Sustainability_performance_of_Espoo_with_selected_EU_cities_2017.pdf